

The Goddard Chemistry Climate Model (GEOS CCM)

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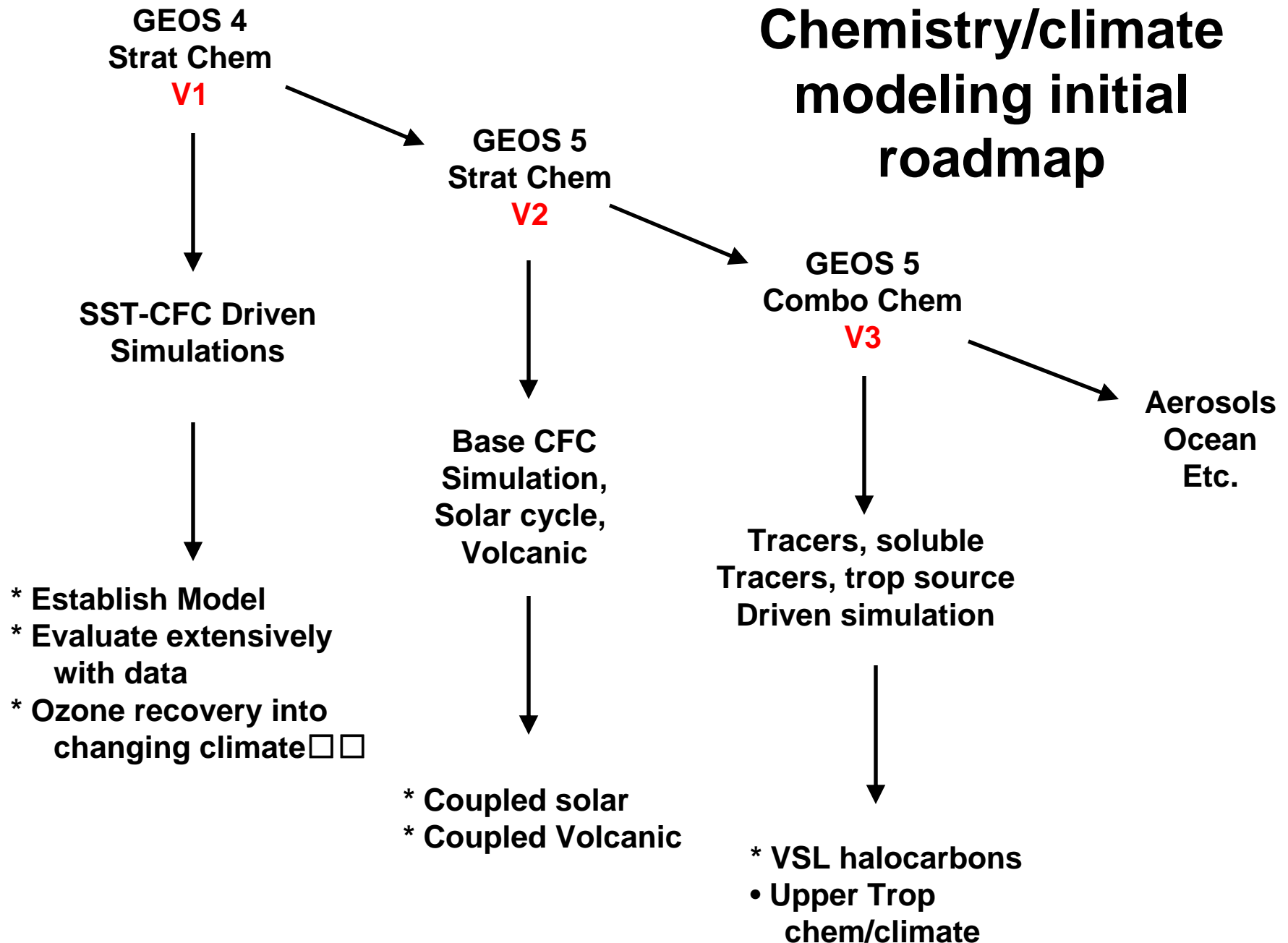
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J. Eric Nielsen

GEOS CCM

- **A joint project of the Goddard Atmospheric Chemistry and Dynamics Branch (ACDB) and the Global Modeling and Assimilation Office (GMAO)**
- **We combine the atmospheric chemistry of the Goddard CTM and the general circulation model of GMAO into a coupled chemistry climate model**

Chemistry/climate modeling initial roadmap



Completed and Ongoing Simulations

V1-GEOS 4 AGCM coupled with stratospheric chemistry

- Time slice 1980 (26 years) Hadley SSTs 1979-2004
- Time slice 2000 (26 years) Hadley SSTs 1979-2004
- Time slice 2020 (26 years) Hadley SSTs 1979-2004
- Time dependent past (1950-2005) Hadley SSTs
- Time dependent past (1950-2005) Hadley SSTs, 2nd ensemble member
- Time dependent future (1996-2099) HadGEM SSTs
- Time dependent future (1971-2050) HadGEM SSTs
- Time dependent future (1971-2053) NCAR SSTs
- Time dependent future (2000-2099) NCAR SSTs
- Time slice 2000 (26 years) repeated 2002 Hadley SSTs
- Time slice 2000 (26 years) repeated 2000 Hadley SSTs
- Time dependent past: low chlorine (1960-2004)
- Time dependent past and future: 1960 chlorine (1960-2022)

V2-GEOS 5 AGCM coupled with stratospheric chemistry

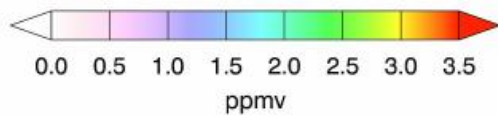
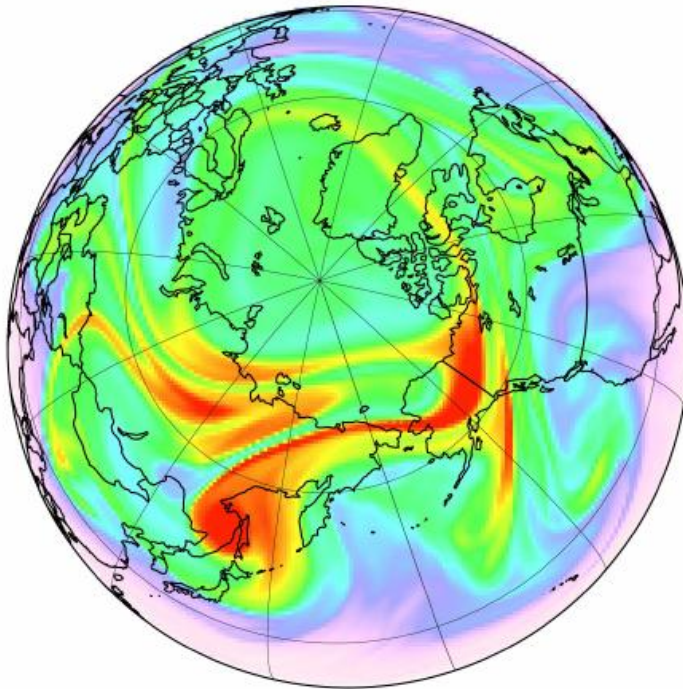
- Time slice 2000 (30 years) Hadley SSTs

GEOS-5 with Stratospheric Chemistry

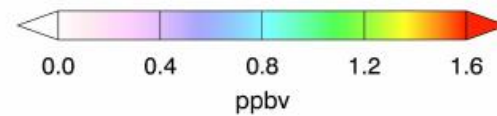
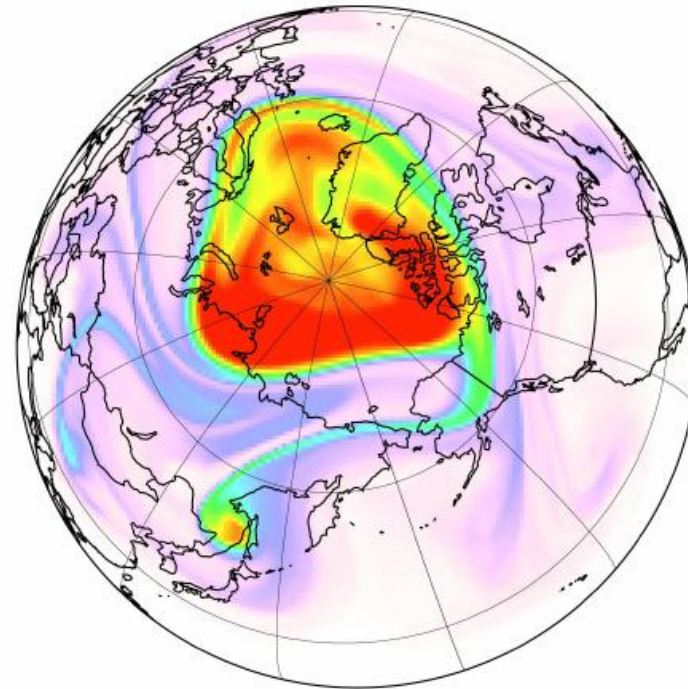
$2/3^\circ \times 1/2^\circ$

70 hPa Thu 1 Apr 2004 (SST)

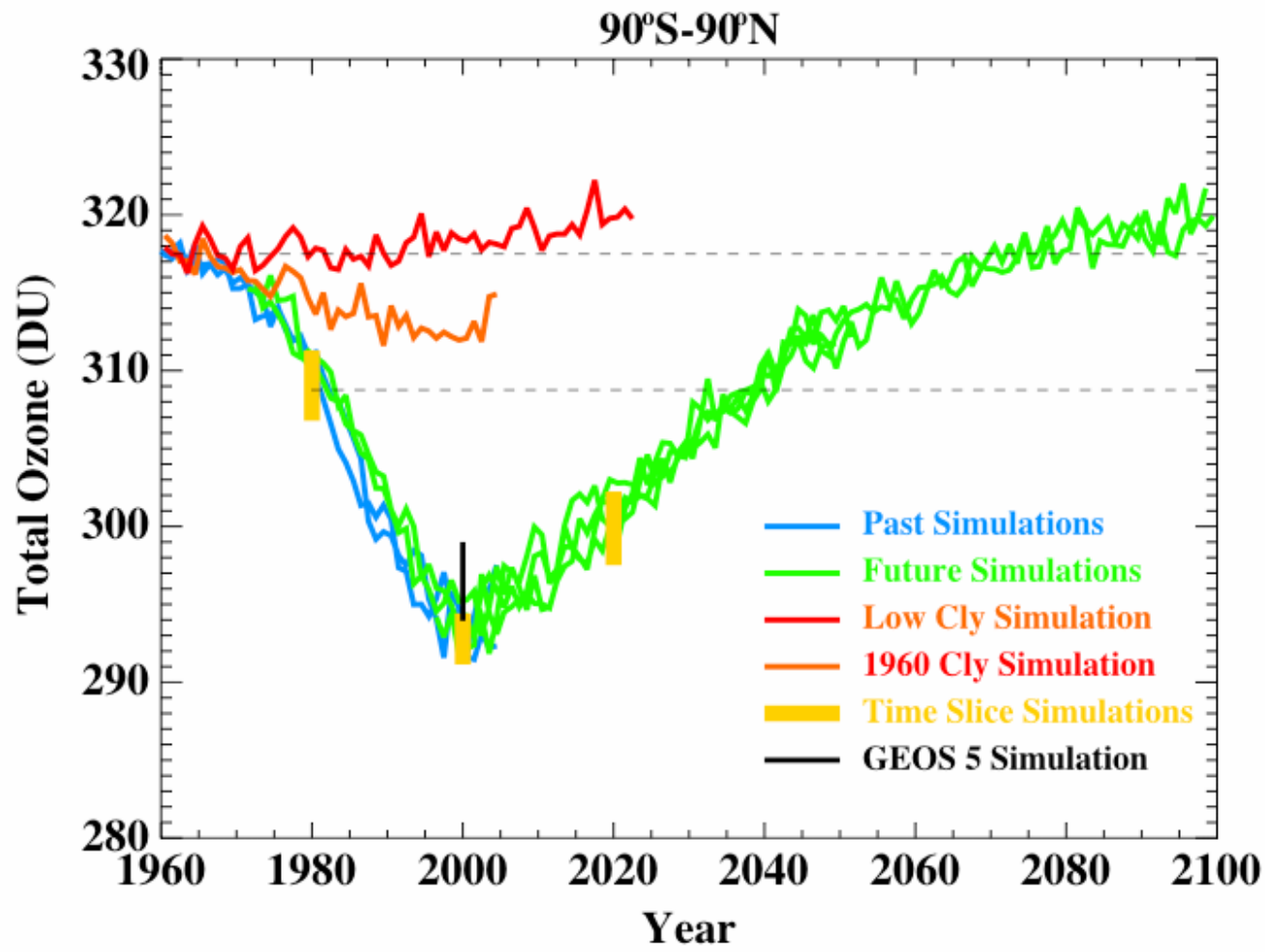
Ozone O_3



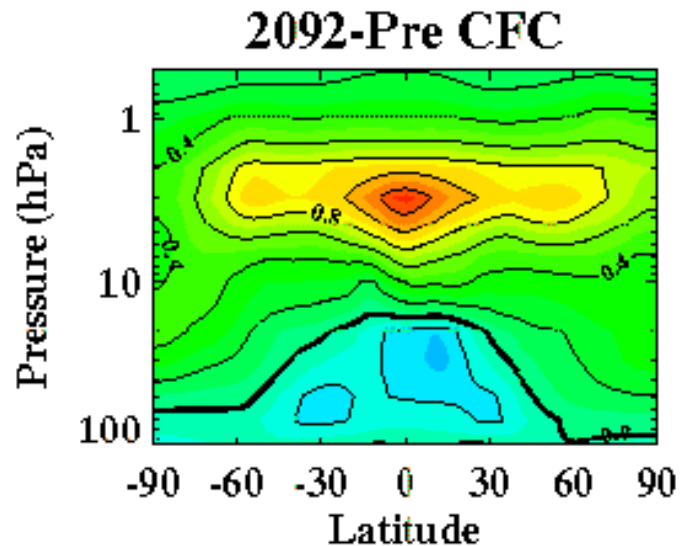
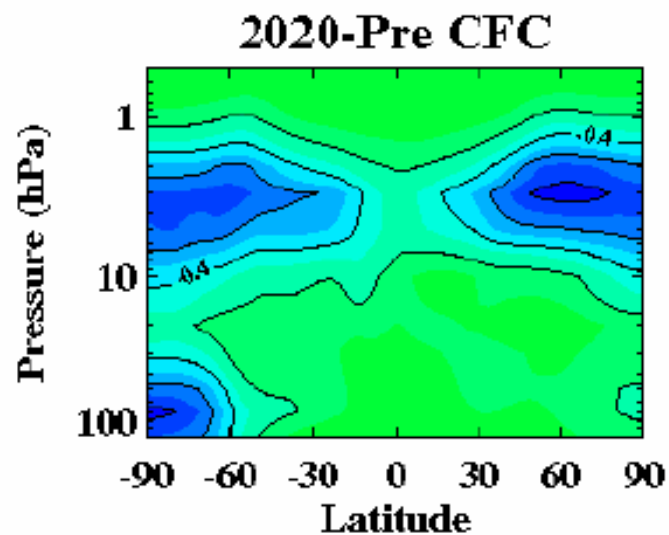
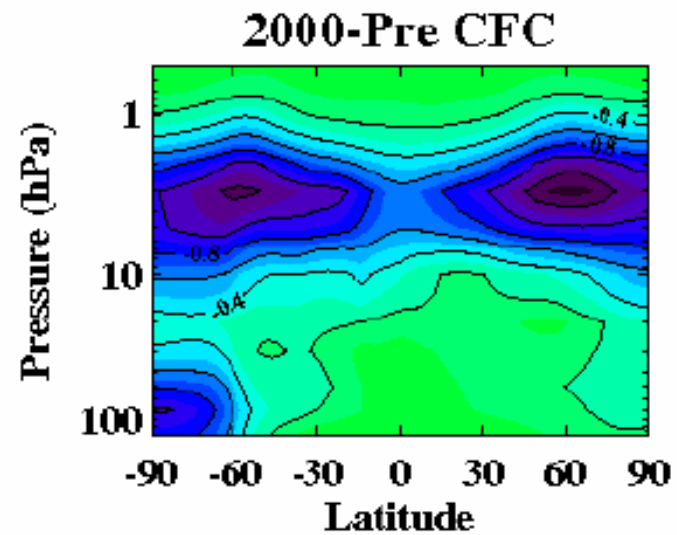
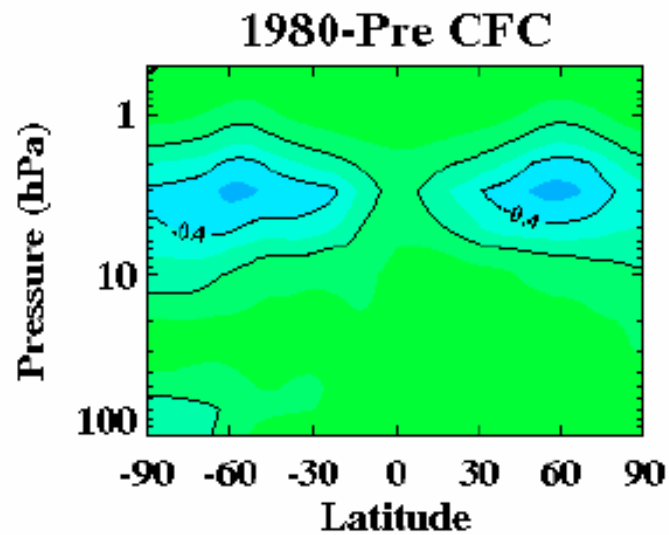
Chlorine nitrate $ClONO_2$



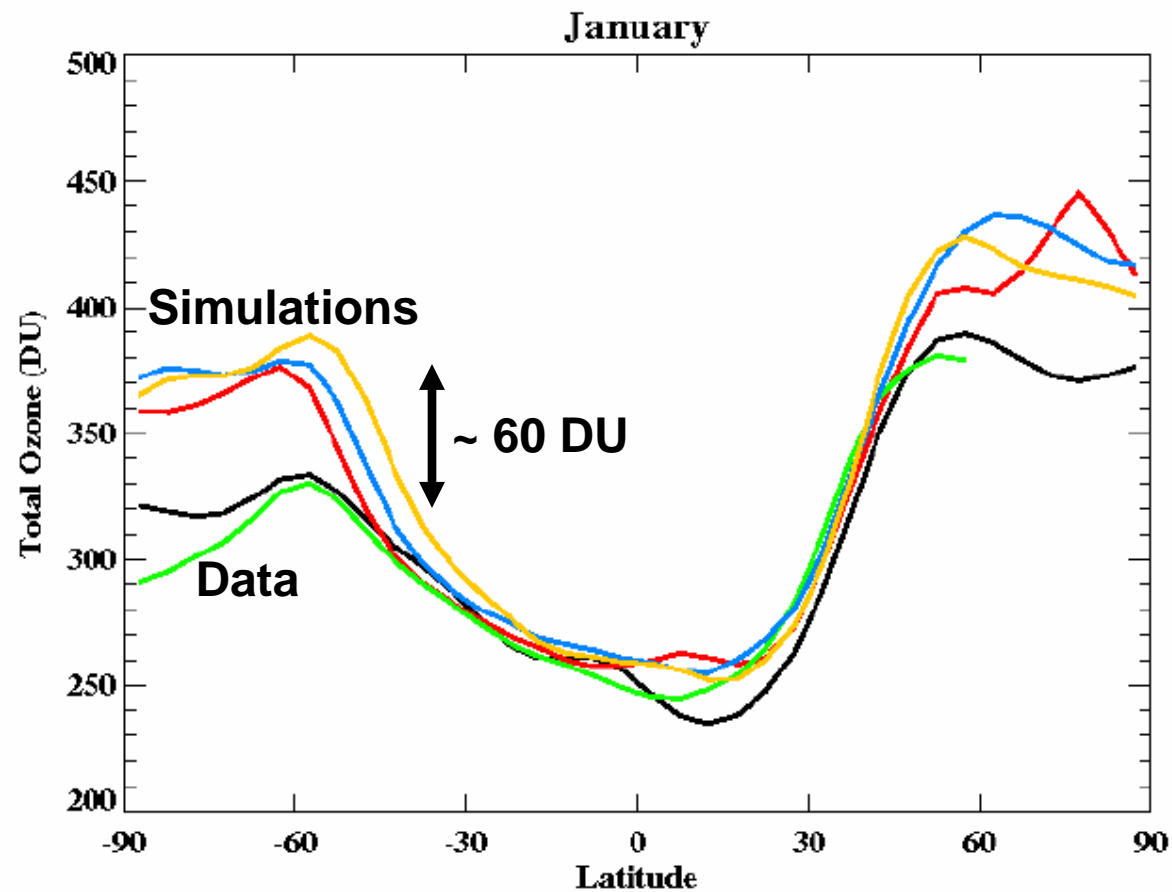
Global Average Total Ozone Summary: GEOS CCM



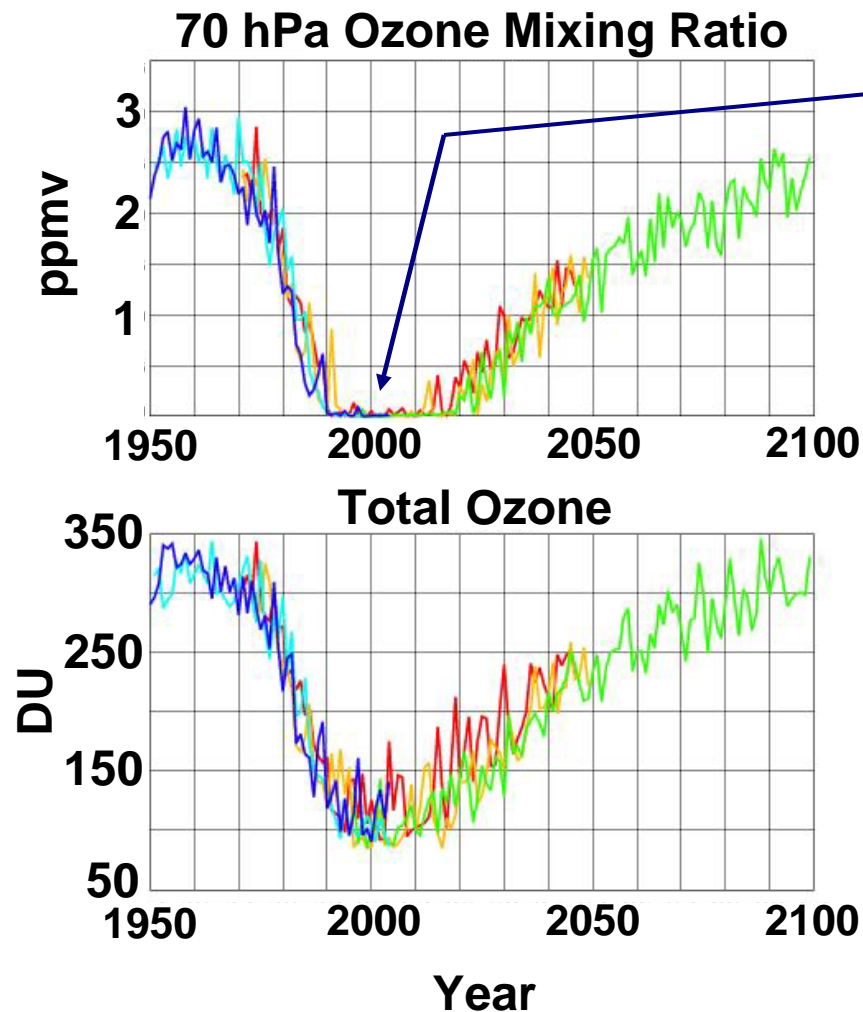
Ozone Changes: Past and Future (ppmv)



Comparison vs Latitude for January, 1980



October Antarctic ozone minima for the five ensemble experiments



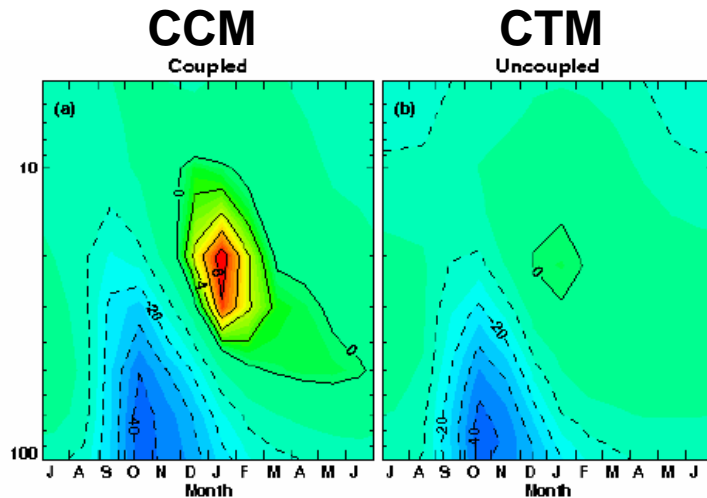
Note zeroes appear until 2010 to 2020 depending on ensemble member

P1, P2: observed SSTs.

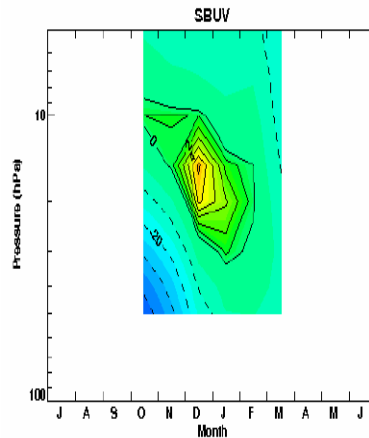
F1, F2: Hadley center simulated SSTs.

F3: NCAR CCSM simulated SSTs.

Antarctic Summer Ozone Increase in Mid-Stratosphere



SBUV Data

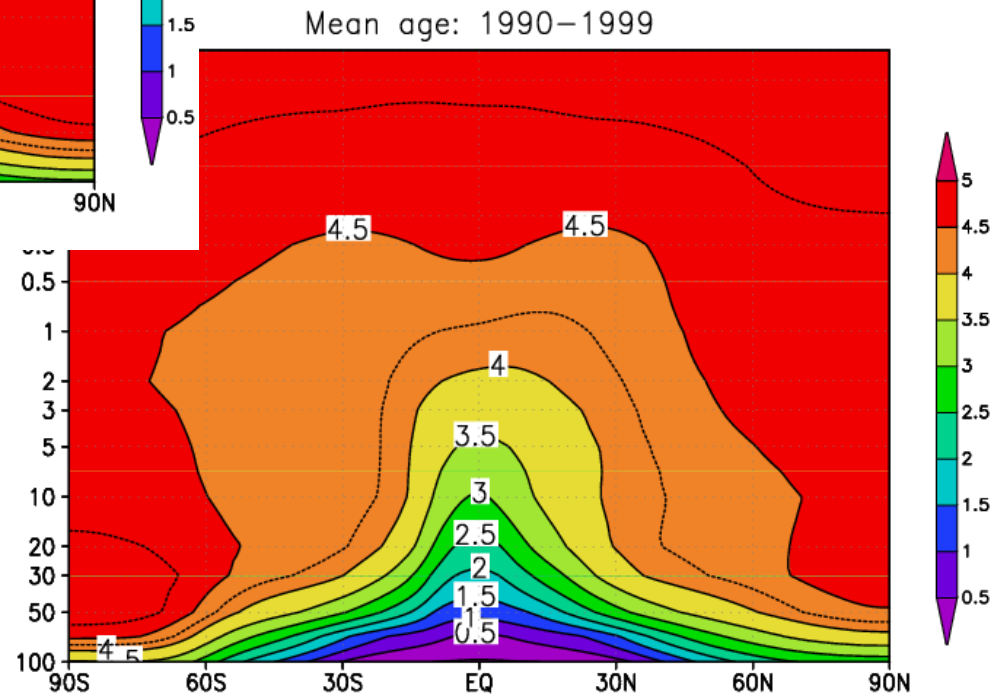
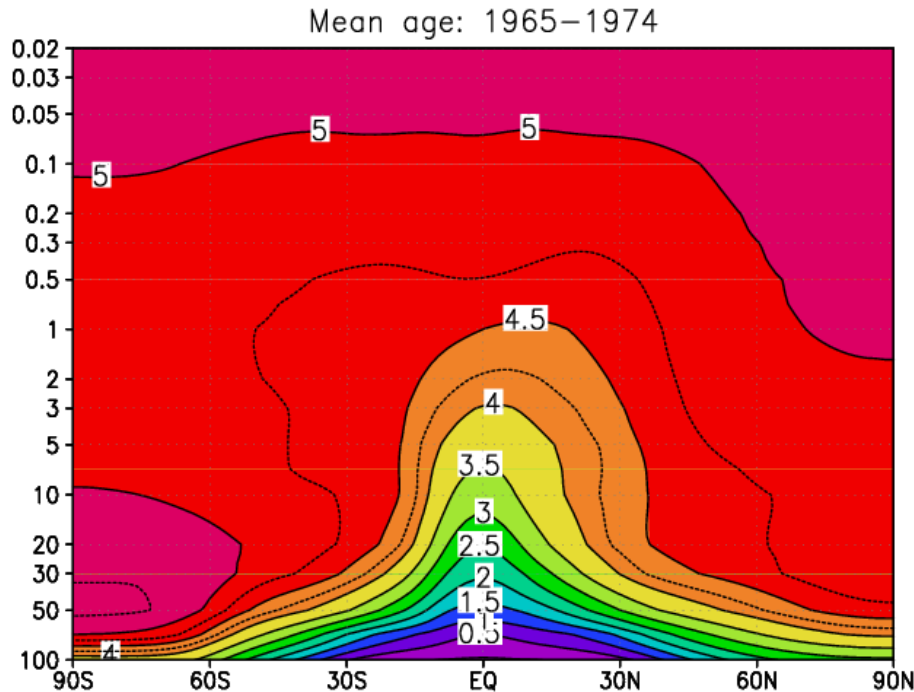


Coupled models show an increase in ozone in the mid-stratosphere of the Antarctic during summer. Uncoupled models do not. Results from a dynamical feedback in which Antarctic lower stratospheric cooling increases latitudinal T gradient, generating a secondary circulation.

Most importantly this effect is found in data (SBUV and sondes) as a 25-year trend. This provides experimental confirmation of one aspect of coupling. (from Stolarski et al., GRL 2006)

Mean Age and its Evolution

From Darryn Waugh

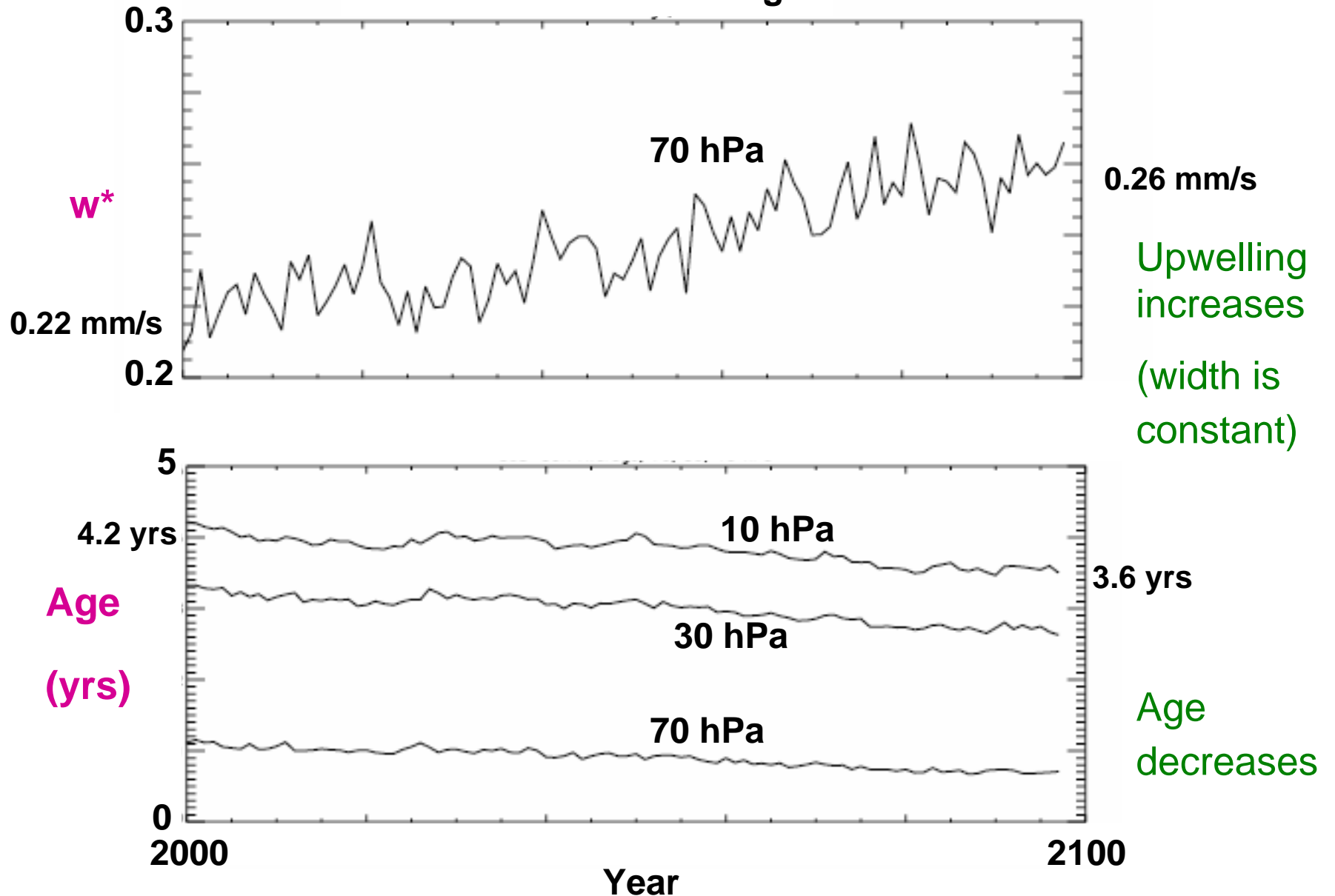


**Virtually all CCMs
show a speed up of
residual circulation
with increased GHGs**

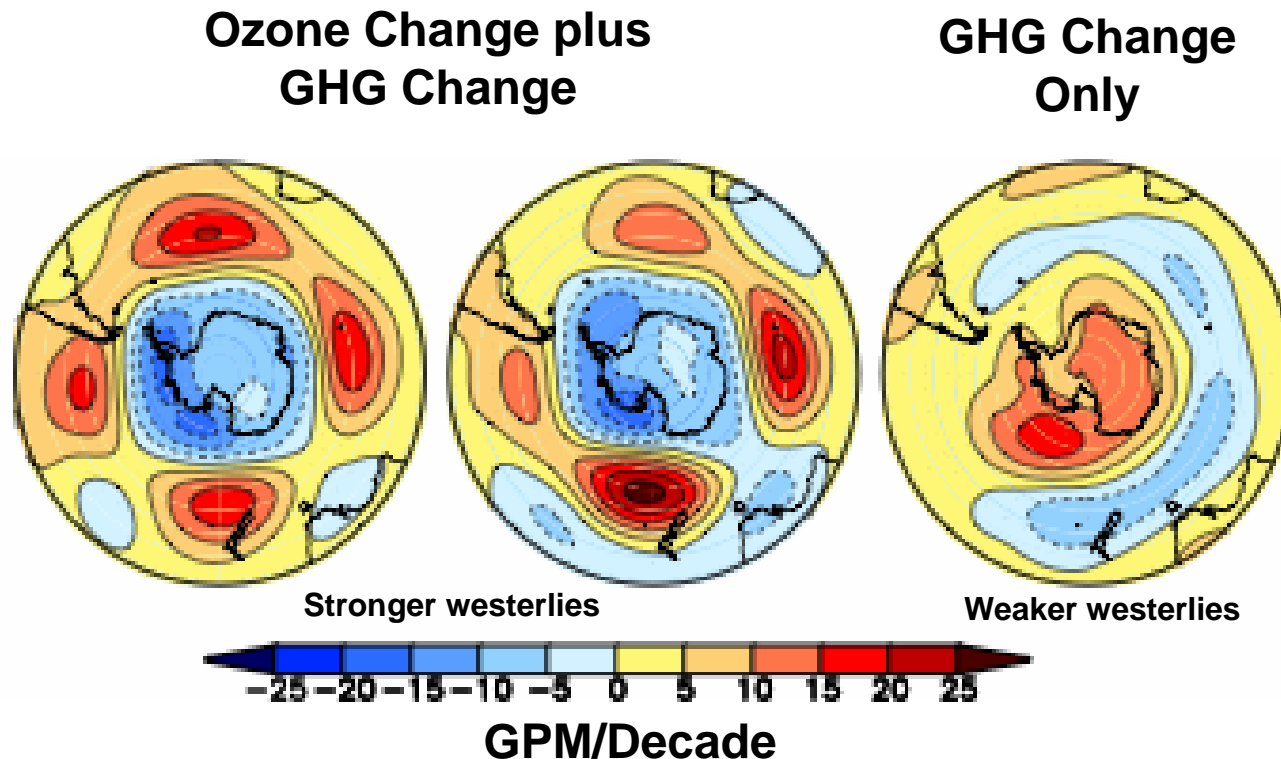
Temporal Variation of w^* and mean age

30°S-30°N Average

From Darryn Waugh

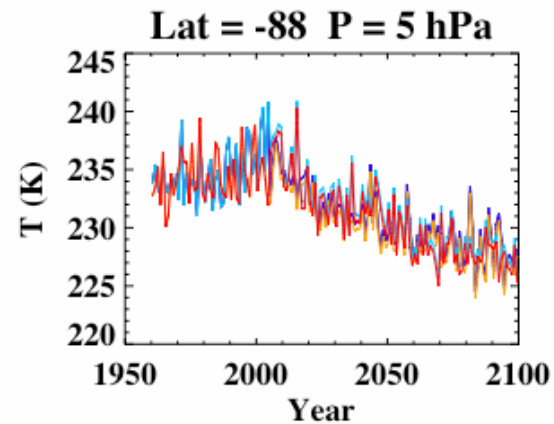
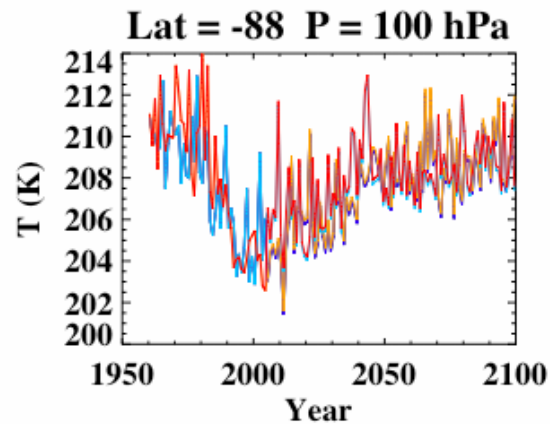
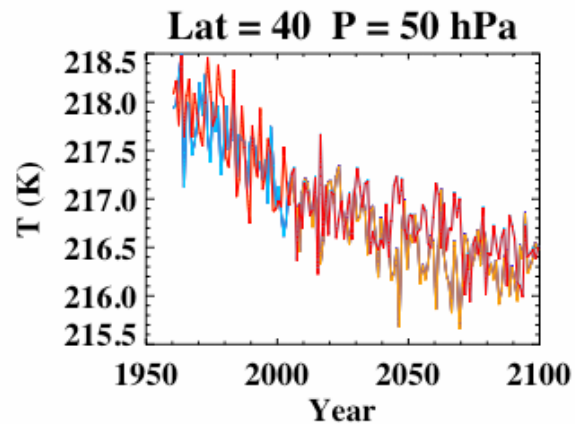
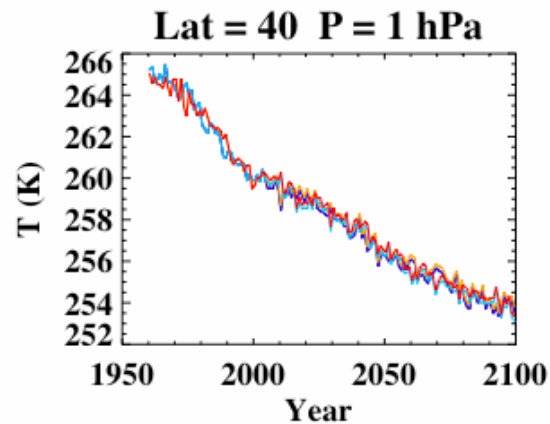


Polar ozone changes have an impact on the Southern Annular Mode



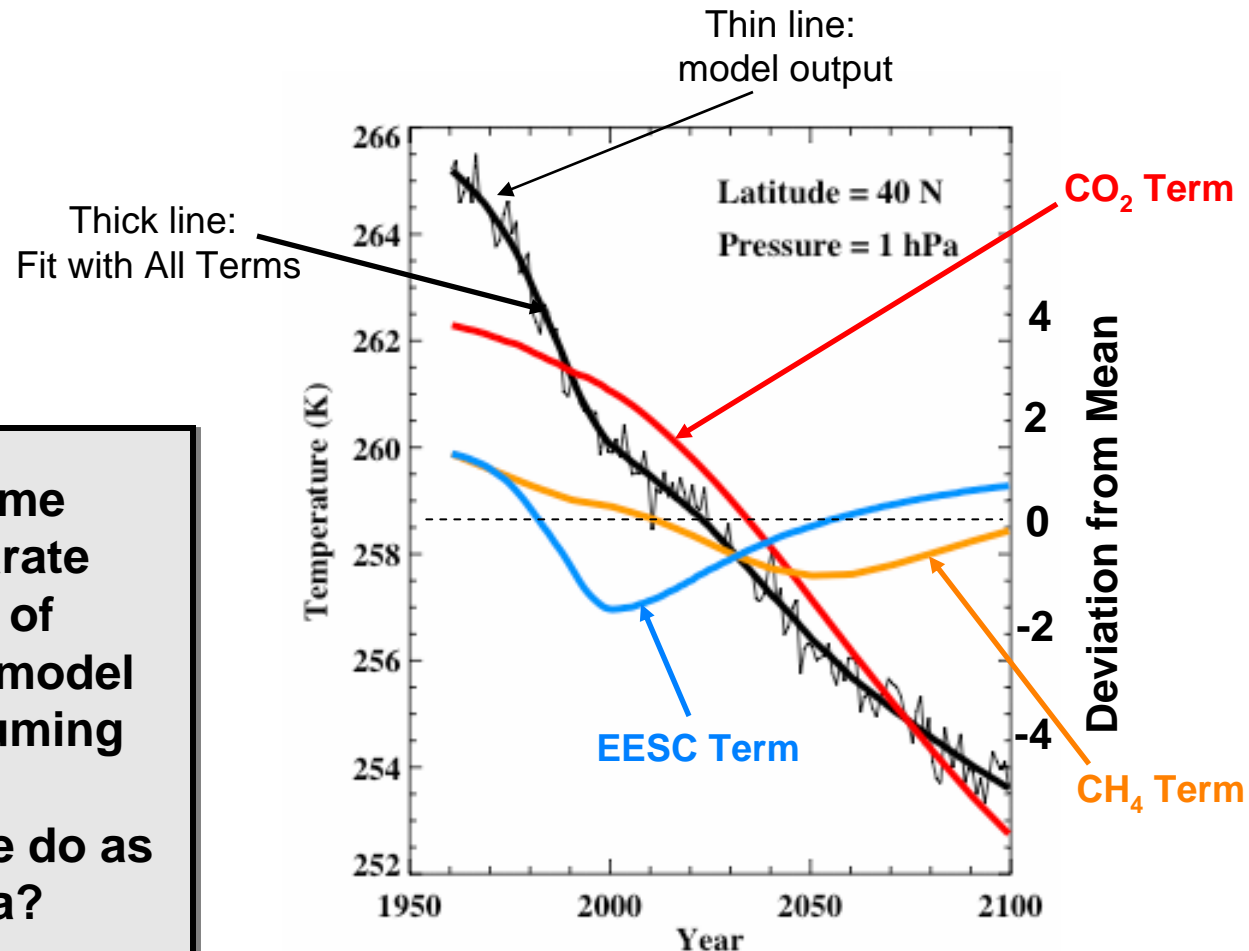
Linear trend (1960-2000) in the 500-hPa Southern Annular Mode in DJF for runs P1 (left), P2 (center) and CFC1960 (right). CFCs are fixed at 1960 values in CFC1960, but grow according to established scenarios in P1 and P2. (from Judith Perlwitz)

140-year constructed time series from 2 past and 4 future simulations



Time-series fit to source gas changes

$$T(t) = a_0 + a_1 \bullet \text{EESC}(t) + a_2 \bullet \text{CO}_2(t) + a_3 \bullet \text{CH}_4(t)$$

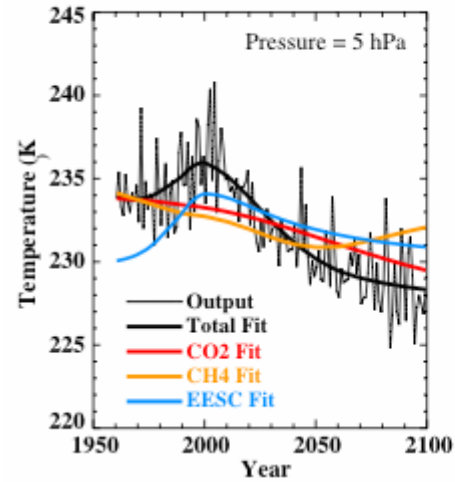


We can use the time signature to separate the contributions of each term to our model simulations (assuming that they linearly combine): Can we do as well with real data?

Same terms fit all locations

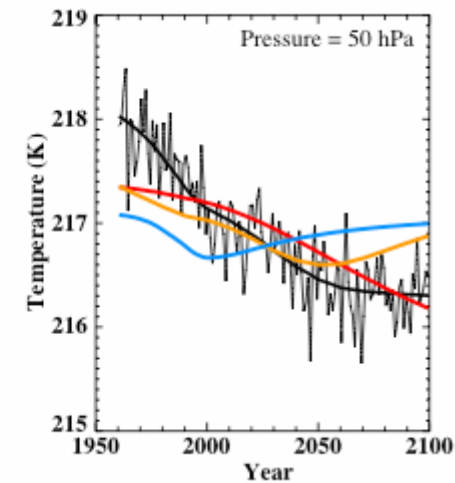
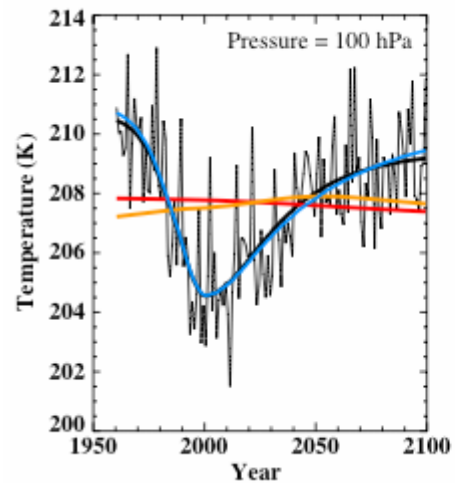
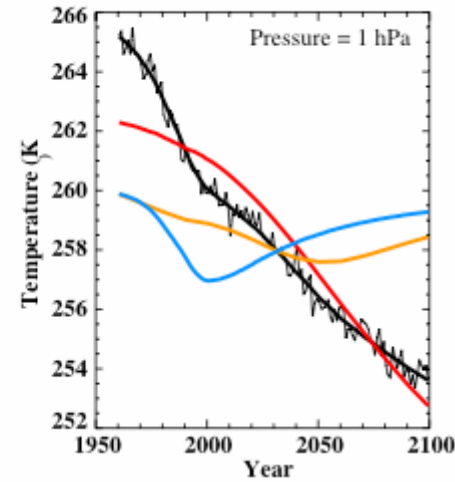
88°S

Latitude = 88S



40°N

Latitude = 40N



GEOS CCM / NASA Goddard



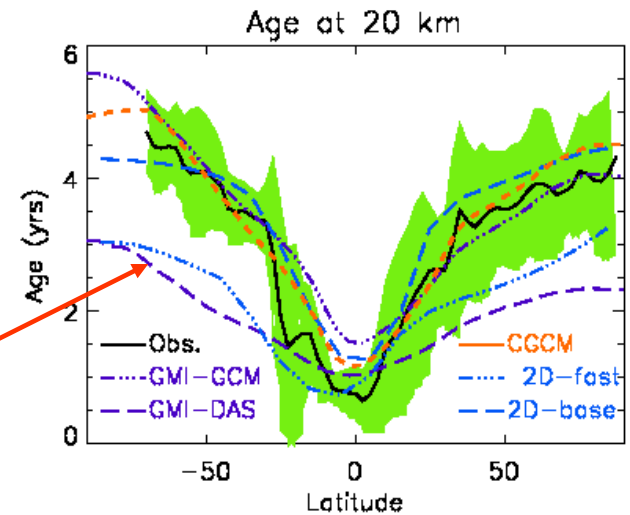
Where we will be in 1.5 years (for next IPCC)

- We will run an extensive set of simulations with GEOS CCM Version 2 (GEOS-5 with stratospheric chemistry):
 - Past (1950-2005) simulations (several ensemble members)
 - Future (2000-2100) simulations.
 - Low chlorine simulation
 - Possibly a no GHG change simulation
 - Past and future **FLUX** boundary condition simulations
 - Several time-slice simulations
- We will do ensembles of transient simulations to estimate chemistry-climate responses to Pinatubo aerosols.
- We will do initial simulation (probably time-slice 2000) with GEOS CCM Version 3 (GEOS-5 with GMI Combo chemistry).
- We will complete our first tests with a coupled ocean model

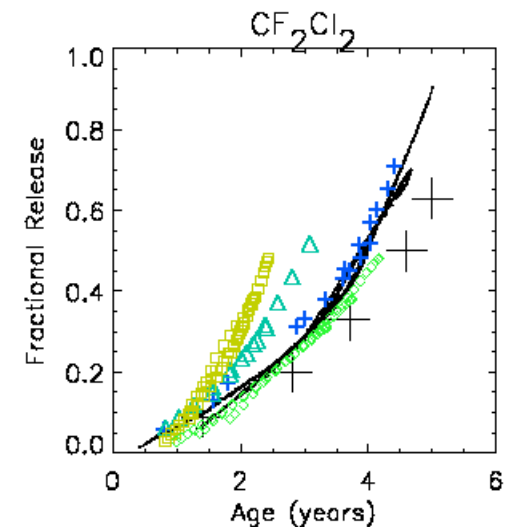
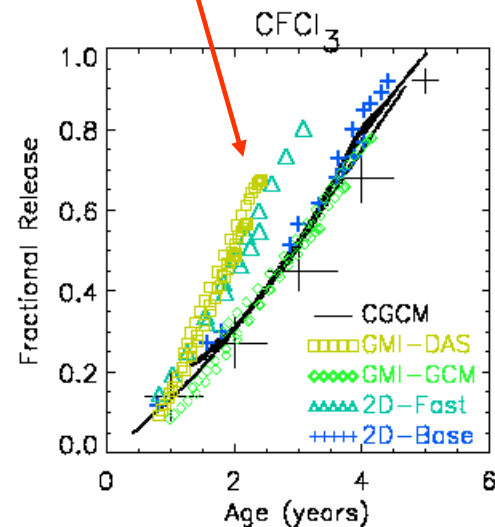
Critical Tests of Model Transport

Combined mean age and fractional chlorine release constrain both age and age spectrum. Fast circulation models fail both. Some models may get mean age correct, but fail this fractional release test. (from Anne Douglass)

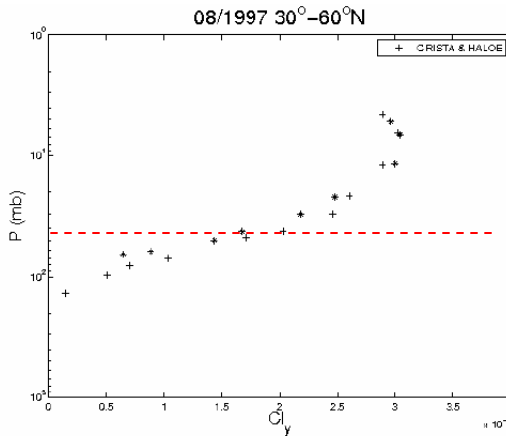
**“Fast”
circulation**



The “fast” circulation models shown are consistent with many of the published lifetimes for CFCs. Models that pass these tests tend to give longer lifetimes (e.g. 56 years for CFCI_3).

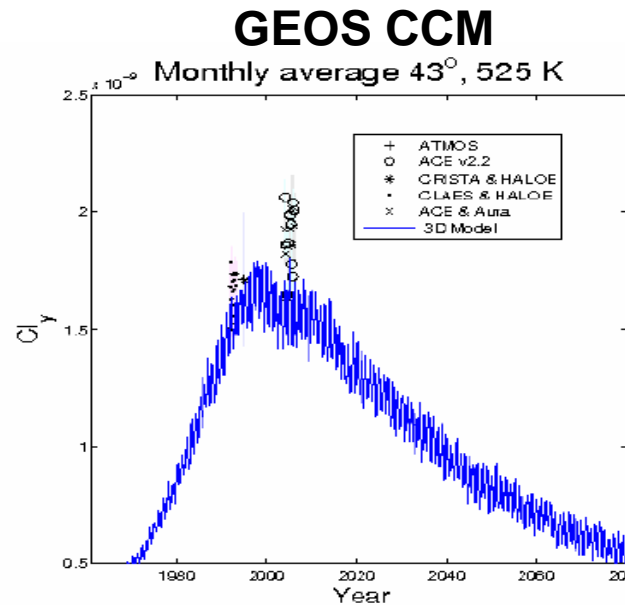


Cly as Model Transport Diagnostic

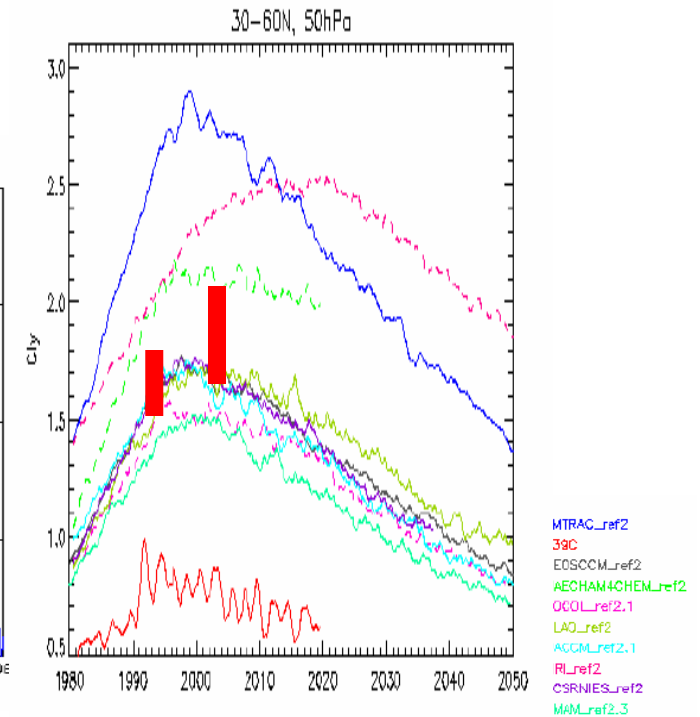


Get upper stratosphere correct because of mixing ratio boundary conditions on CFCs and complete release

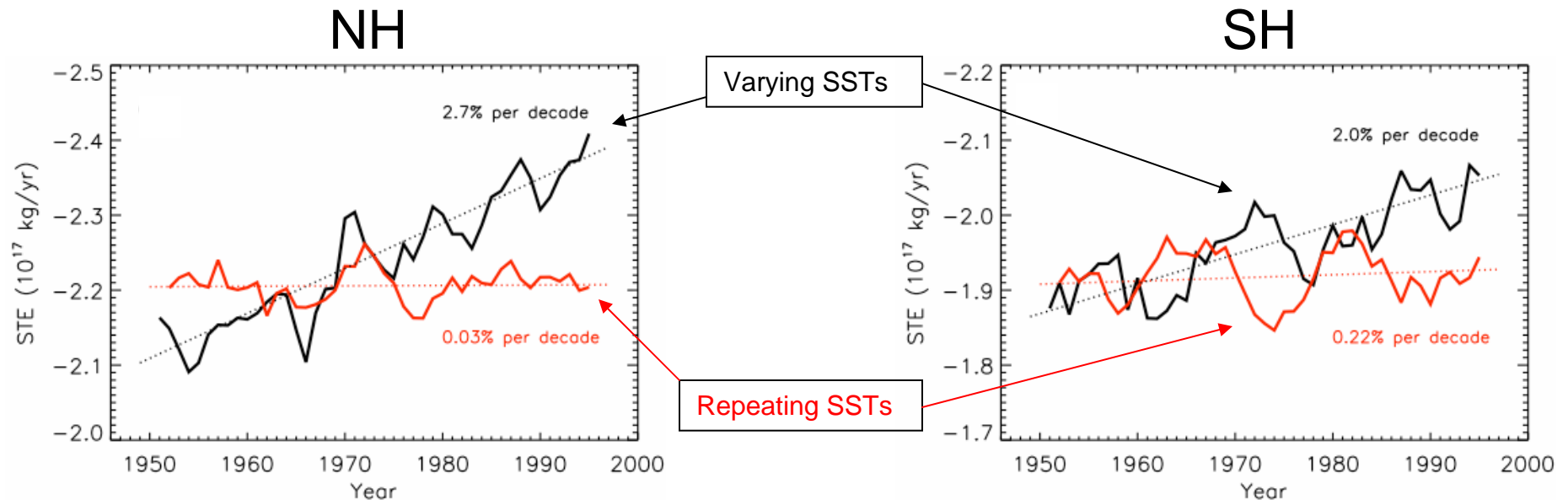
Profile shape is more difficult: requires proper balance between strength of circulation and photolysis.



CCMVal intercomparison

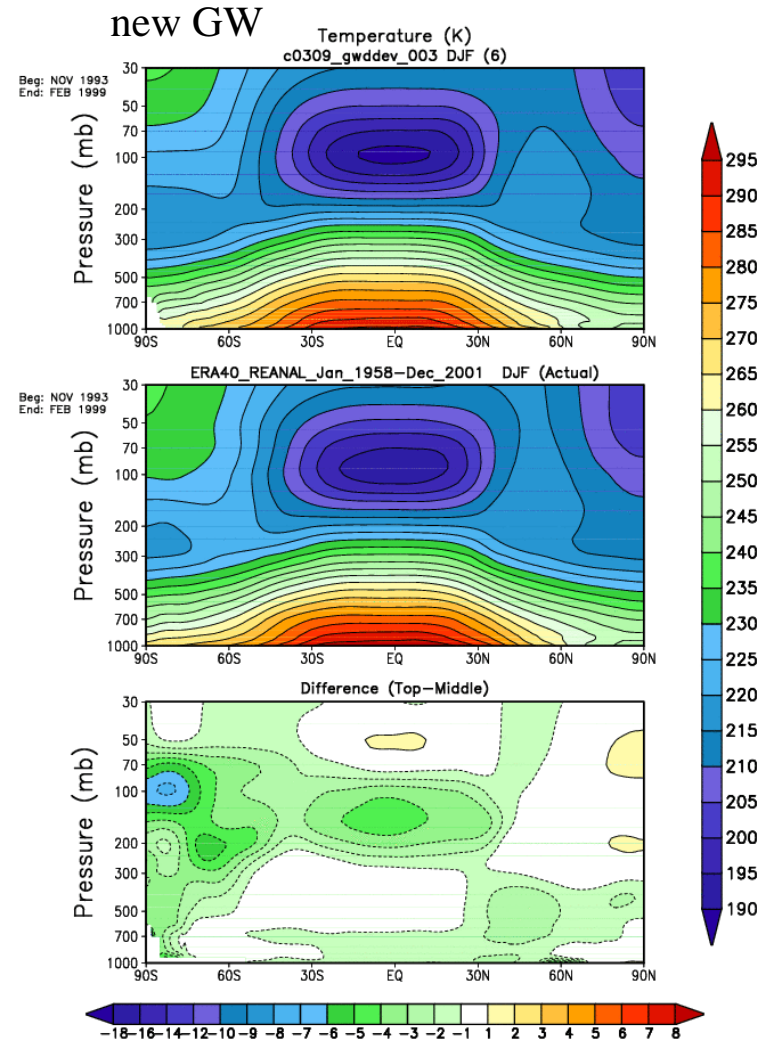
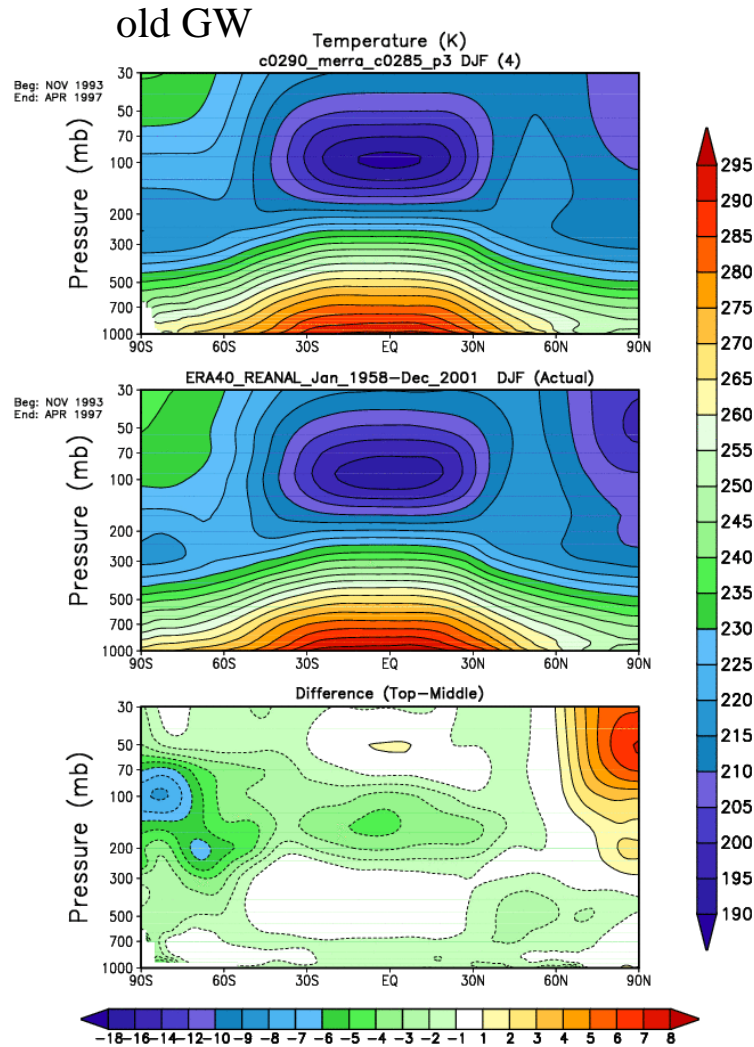


FVGCM Results- Midlatitude STE (SST Forcing)



- STE can be a single-valued indicator of the BD circulation in 50-year simulations.
- STE trend is comparable with trends found in other studies using increasing GHGs with consistent SSTs.
- Our results suggest refraction of vertically propagating waves may play a significant role.

zonal mean T compared w/ ERA40 re-analyses (actual not climo)



Ozone Changes Relative to 1980

